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BREEDING VARIETIES OF POTATO RESISTANT TO DISEASES AND INSECT INJURIES[1]

F. J. Stevenson[2]

We are confronted with a potato surplus of nearly 50 million bushels this year. Such a surplus will no doubt result in low prices and large dump piles. Why, then, with too many potatoes being produced should we spend more time and money breeding new varieties to increase yields further? A similar question could be asked about the use of certified seed, fertilizer, fungicides, insecticides, and new equipment. A sure way to eliminate surplus is to stop the seed-certification program, cut the applications of fertilizer, and discontinue disease controls.

Millions of dollars are spent by growers each year to prevent the destruction of the potato crop by diseases and insects. The development of new varieties resistant to diseases and insects is just another method of control, a co-partner with other methods. New varieties are produced not so much to increase yields as to help the farmer in his battle against crop enemies and to reduce the cost of production and uncertainties in yields. Usually these go hand-in-hand.

Early Potato Breeding by Growers and Amateur Breeders

Potato breeding in the United States began about 100 years ago. From 1843 to 1847 severe epidemics of late blight destroyed many of the potato crops in the United States, and many attempts were made to breed resistant varieties.

During the latter half of the 19th century growers and amateur breeders produced several hundred potato varieties, a few of which are grown commercially today but none of which was resistant to late blight. Fungicidal controls that made possible the production of susceptible varieties were devised, and for a time potato breeding in the United States was allowed to lapse.

Early Potato Breeding by the United States Department of Agriculture

In 1910 potato breeding was resumed not by growers and amateur breeders but by the United States Department of Agriculture under the leadership of Dr. William Stuart. At that time the only disease resistance sought was that against the late blight fungus. Some years later it became evident that the virus diseases were a vastly greater menace to potato production than late blight, because potato viruses are transmitted from one crop to the next through tuber infection and cannot be controlled by fungicidal application to the foliage or by seed treatment.

The widespread occurrence of potato virus diseases convinced Dr. C. F. Clark, who assumed the leadership of the potato-breeding work in 1919, that it was necessary to develop varieties resistant to such diseases. Dr. Clark's first step in that direction was toward the development of

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varieties resistant to mild mosaic, one of the commonest virus diseases in Maine. At that time, there were no formal tests for resistance to viruses, but natural epidemics occurred every year, and numerous seedlings and seedling varieties produced by Dr. Clark had to be discarded because they had contracted one or more of the virus diseases. Seedling varieties that escaped virus infection and were later found to be resistant were selected. These were crossed with one another and with other seedlings and varieties in an attempt to obtain new types with a high degree of resistance to mild mosaic, combined with desirable tuber characters, good habit of vine growth, and productiveness. How well Dr. Clark succeeded is shown by the new varieties Katahdin, Chippewa, Houma, and Earlaine, all immune from mild mosaic in the field. The seedling variety No. 24642 that entered into the parentage of all of these and from which they inherited their resistance to mild mosaic was one produced in 1913 by Dr. Stuart.

In working for varieties that were immune from mild mosaic, Dr. Clark succeeded in selecting those immune from virus X, which is latent in some varieties but cuts the yield as much as 30 per cent. One of these, 41956, was first grown in 1921. It was from a cross of a selfed line of a South American variety, Villaroella, and the seedling 24642, mentioned previously. Because the reaction of many varieties to virus X was latent, and there were no formal tests for virus resistance, Dr. Clark did not know that 41956 was immune from virus X until about 10 years after it was first grown, when E. S. Schultz and W. P. Raleigh discovered this fact.

In addition to the work carried on by the United States Department of Agriculture in Maine, potato breeding was being done in Minnesota and New York. In Minnesota F. A. Krantz was specializing on earliness and experimenting with breeding methods, especially those involved in selfing and recombination of inbred lines. In New York State Donald Reddick, of Cornell University, was beginning his work of breeding varieties immune from late blight and J. R. Livermore, also of Cornell University, was selecting improved varieties from clones of Rural and Green Mountains.

The National Potato-Breeding Program

The results obtained in Maine, Minnesota, and New York created a general interest in potato breeding, and in 1929 new appropriations made possible the expansion of the program. Dr. E. C. Auchter, then Chief of the Division of Horticultural Crops and Diseases, brought together at Chicago a group of horticulturists representing a number of potato-producing States to propose plans for developing and expanding the investigations. The result was the National Potato-Breeding Program, the work of which was to be done and is being done by State agricultural experiment stations in cooperation with the United States Department of Agriculture. Formal agreements of understanding were immediately entered into between the Department and 9 States. Now (1955) there are 28 such agreements and informal cooperation with 11 other States and 3 Territories, making a total of 39 States and 3 Territories at present cooperating in a more or less extensive way. Informal cooperation

is carried on also with Canada and a number of other foreign countries. The author has been in charge of this program since 1930.

After the reorganization, the Federal breeders and pathologists joined forces. The virus work was expanded in Maine, and it was not long before Dr. E. S. Schultz confirmed Dr. Clark's judgment of resistance to mild mosaic in a number of seedling varieties and showed that 41956 was immune from virus X.

Horticultural characters, yield and market and cooking qualities always were given first consideration, but it was evident that a number of major diseases were becoming of increasing importance, and breeding for resistance to each of them should be undertaken.

Materials and Methods

Potato breeders in the United States made use of many domestic and foreign varieties classified as *Solanum tuberosum* and isolated a great array of valuable characters, recombinations of which will give us in the future, varieties far superior to any that are grown today.

Species and Species Hybrids

Species hybrids have been made from time to time, but so far the most important character to be obtained from such material is immunity from some of the physiological races of late blight. However, it is a standard rule among plant breeders that not only should the cultivated forms be used but also the wild relatives should be investigated. Needless to say, some of the wild relatives have been used in potato-breeding work in this country and in Europe since early in the 20th century, and some of the characters that have been found in what is known as *Solanum tuberosum* may have come from species hybrids.

In recent years the work with wild species has been expanded greatly. Such work is carried on at the Plant Industry Station, Beltsville, Maryland, and at a number of State agricultural experiment stations. In 1954 at the Plant Industry Station, 47 species and 28 interspecific hybrids were grown for crossability and cytological studies. Following controlled pollinations, seed was obtained from 29 self or intraspecific pollinations and from 198 interspecific pollinations. Seed was obtained also from 59 pollinations involving interspecific hybrids. Special techniques such as doubling the chromosomes with colchicine are used in this work with varying degrees of success.

Solanum tuberosum or Cultivated Varieties

The improved varieties of the future may result from species hybrids, but characters available in the named and numbered varieties of *Solanum tuberosum* are sufficient to keep several breeders busy for many years.

Judging from the numerous characters that have been isolated *Solanum tuberosum* is at present a very heterogeneous species, the heterogeneity resulting from mutations or species hybrids. A list of characters that have been found in varieties and seedlings of *S. tuberosum* include: Wide adaptation; various seasons of maturity; many shapes; many skin and flesh colors; various degrees of russeting; various depths of eye; wide

range in yielding capacity and in dry-matter content; resistance to the diseases mild mosaic, latent mosaic, rugose mosaic, leaf roll, net necrosis, yellow dwarf, late blight of the vines, tuber rot initiated by the late blight fungus, common scab, potato wart, verticillium wilt, brown rot, ring rot, and hopperburn; and resistance to flea beetle and aphid injuries.

Economic Results

In addition to isolating a large number of valuable characters in genetic materials, learning something of the breeding behavior of those characters, and experimenting with new technics we have bred and released to growers a relatively large number of varieties. Some of these proved valuable and are widely grown; others are limited in their range of usefulness but are valuable under certain conditions; and others have fallen by the wayside. A number of old varieties also have gone out of production.

The summary of certified seed-potato production, prepared by the Section of Agricultural Economics, United States Department of Agriculture, in 1954 listed fewer varieties than in 1948. In 1948, 51 varieties were found in the certified lists. Twenty of these were old varieties produced during the last half of the 19th century. The other 31 were varieties released to growers since the organization of the National Potato-Breeding Program. In 1954, 11 old and 35 new varieties were listed. In 1948 the 20 old varieties accounted for approximately 56 per cent of the certified seed in the United States. In 1954 the 11 old varieties constituted about 38 per cent of the total certified seed.

Resistance to Diseases

In our program we have reached a number of the objectives of breeding for disease resistance as the following discussion and lists of varieties will show. The named varieties in the lists have been released to growers; the numbered varieties are maintained for breeding purposes or future release.

Mild Mosaic. Mild mosaic caused by the interaction of virus A and virus X is one of the so-called "running out" diseases of the past, to which such a variety as Green Mountain is extremely susceptible. Varieties immune from this disease require less isolation and roguing in the production of certified seed. Named and numbered varieties field immune to mild mosaic are Cherokee, Chippewa, Earlaine, Houma, Katahdin, Kennebec, Merrimack, Saco, Sebago, Teton, Sequoia, B 595-76, B 606-3, B 606-37, 792-88, 792-94, B 922-8, B 926-9, 927-3, B 929-6, and many other related seedling varieties.

Latent Mosaic. Latent mosaic may be caused by any one of several strains of the virus X group, which are classified according to their virulence. The disease may not be visible on the plants but may cut the yield 20 to 30 per cent. To avoid such losses expensive programs are in operation in a number of States and countries to produce X-virus-free seed stock of susceptible varieties. Immune varieties will obviate such losses and programs. Named and numbered varieties immune in the field and in grafts are Saco, 41956, 792-88, 792-94, B 595-76, B 606-3, B 606-37,

B 922-8, B 926-9, B 929-6, B 2962-6, B 3172-13, B 3298-34, and other related seedling varieties.

Veinbanding Mosaic. Virus Y causes veinbanding or veinclearing and when associated with virus X rugose mosaic. These diseases are severe in some sections of the country and are rather difficult to control. A weak resistance to veinbanding exists in Chippewa and Katahdin; but higher degrees of resistance are to be found in the following numbered varieties: B 524-53, B 922-3, B 922-8, B 1172-14, B 1172-16, B 2067-52, B 2068-23, B 3209-29, and other related varieties and North Dakota Nos. 457-1 and 457-1-35.

Yellow Dwarf. In some seasons yellow dwarf caused heavy losses in the Rural varieties in New York, Michigan, and Wisconsin. We have had no program for breeding for resistance to yellow dwarf, but after Sebago was released it was found to be highly resistant to this disease by scientists in Wisconsin.

Leaf Roll. The virus causing leaf roll is a menace to potato plants in two ways. It reduces yields and causes net necrosis in the tubers. No varieties highly resistant to leaf roll have been released, but Houma and Katahdin are moderately resistant. Several seedling varieties are highly resistant to leaf roll in the field: B 24-58, B 24-78, B 294-38, B 579-3, 927-3, B 2834-3, B 2925-23, B 2962-6, and a number of others. Some of these may be released if their other characters are found satisfactory.

Net Necrosis. Net necrosis in the tubers, caused by current-season infection with the leaf-roll virus, is a limiting factor in the production of the Green Mountain variety in Maine and sometimes takes heavy tolls from the Russet Burbank grown in Idaho. In some sections in Maine growers had to grow immune varieties so that they could produce potatoes that could be sold. Fortunately, it is easier to breed varieties immune from net necrosis than it is to produce leaf-roll-resistant sorts. Varieties immune from or highly resistant to net necrosis are Cherokee, Chippewa, Earlaine, Houma, Katahdin, Kennebec, Merrimack, Saco, and Sebago.

Late Blight. Some progress can be reported in breeding for resistance to late blight, but the solution of the problem is far from complete. The causal fungus continues to mutate, giving new physiological races. Epidemics of the disease vary in severity in response to different climatic conditions. There are apparently two types of resistance. One is found in cultivated varieties such as Sebago, which is not immune from any of the races but moderately resistant to all. The other type is found in varieties related to *Solanum demissum* from which can be obtained 4 or 5 genes each of which gives immunity from one or more of the many physiological races that have been isolated. A combination of the 5 genes will presumably give immunity from all the races known at present. As far as we know, no variety has been produced combining the 5 immunity genes with the many genes necessary to produce a commercial variety. However, we have a number of seedling varieties that are immune from the common race of the late blight fungus and to several of the specialized races. Named varieties moderately resistant to all races of the late blight fungus prevalent in the United States but not immune from any of them are Menominee, Ontario, Potomac, Saranac, Sebago, and Sequoia. Named and numbered varieties immune or nearly immune from the common race are Boone, Cherokee, Delus, Kennebec, Merrimack, Plymouth,

Pungo, B 75-4, 96-28, 96-56, B 355-24, B 595-76, B 606-3, B 919-15, B 926-9, B 929-6, B 962-3, B 1270-7, B 2131-3, B 2837-12, B 2895-3, B 2896-10, B 3102-3, B 3201-22, and B 3355-3. A number of seedling varieties are highly resistant to several physiologic races but none of these has been released. Among these are B 922-3, B 922-6, B922-18, B 3405-1, B 3406-3, B 3407-3, B 3508-8, and B 3516-11.

In 1954 climatic conditions in Maine were ideal for the development of the late blight fungus. Cool, cloudy weather and frequent intermittent showers prevailed throughout the growing season. At least 11 physiologic races of the late blight fungus were found in the field test plots, and although numerous seedling varieties were killed early in the season, a small percentage were immune from or highly resistant to the fungus. Under these conditions the performance of the new late-blight-resistant varieties Delus, Kennebec, Merrimack, and Saco in comparison with 2 susceptible varieties was outstanding. These 6 varieties were given 4-spray treatments. The results of these are given in table 1.

TABLE 1.—*Reactions of six varieties of potato to various sprays for the control of late blight and insect injury as reflected in yields*[1] *and percentage solids.*[2] *Aroostook Farm, Presque Isle, Maine, 1954.*

	Sprays, Yield, and Percentage Solids											
	Water			DDT[3]			Basic Copper			Basic Copper + DDT[3]		
	U.S. No. 1		Solids	U.S. No. 1		Solids	U.S. No. 1		Solids	U.S. No. 1		Solids
	Bus.	Per cent	Per cent	Bus.	Per cent	Per cent	Bus.	Per cent	Per cent	Bus.	Per cent	Per cent
Green Mountain	72	35	16.9	72	38	17.4	224	69	20.1	287	73	20.9
Katahdin	93	51	15.8	114	52	15.5	269	80	17.4	271	81	17.4
Delus	414	95	20.1	384	95	19.9	430	96	20.9	448	96	21.7
Kennebec	567	94	19.1	560	94	18.7	608	94	20.5	646	91	20.7
Merrimack	409	92	19.7	480	92	19.9	486	94	21.6	540	94	21.7
Saco	553	88	19.0	608	88	19.0	637	89	21.4	674	90	21.6
L.S.D. at 5 per cent level	60		.8	60		.8	60		.8	60		.8

[1]Yields given in bushels of U. S. No. 1 potatoes.
[2]Percentage solids based on the specific gravity of the tubers.
[3]Parathion was added to one spray.

The 4 resistant varieties produced relatively high yields and percentage solids without the application of a fungicide, but the susceptible varieties were almost total failures. Sprayed with basic copper every 7 days the resistant varieties yielded somewhat higher than they did without spray but the susceptible varieties were still low in yield. The dry-matter contents of the tubers of all 6 varieties produced in the plots sprayed with copper were higher than when they were grown without copper spray. Results of these tests indicate that it pays to grow blight-resistant varieties and in bad blight years to spray them with a fungicide. Although good yields and fair dry-matter content were produced without the

application of a fungicide better results were obtained when the plants were sprayed with copper, demonstrating the fact that genes for resistance and control measures can be co-partners.

Dry Rot. Resistance of tubers to dry rot initiated by the late blight fungus is often more important than resistance of the foliage. In years of blight epidemics heavy losses of potatoes in the field and in storage are due to dry rot. The tubers of such varieties as Cherokee, Delus, Kennebec, Merrimack, Saco, and Sebago are resistant to dry rot provided they are not injured in the harvesting and handling processes.

Early Blight. Early blight often causes severe damage to potato foliage and sometimes injury to the tubers. No formal program of breeding for resistance to early blight has been carried on, but some of the varieties, notably Merrimack, have shown resistance to this disease in test plots at Salisbury, Maryland.

Common Scab. Many domestic and foreign varieties have been tested for reaction to the common scab organism. Most old American varieties are very susceptible, but a few such as Russet Burbank, Russet Rural, and White Rose usually show a moderate degree of resistance. Foreign varieties such as Hindenburg, Jubel, Ostragis, Rheingold, Arnica, and Ackersegen vary somewhat in their reactions, but all are more resistant than most of the old American varieties. None of the foreign varieties is immune or has any commercial promise in the United States, but when used as parents in crosses with domestic sorts many scab-resistant named and numbered varieties have been produced; among these are Cherokee, Cayuga, Menominee, Ontario, Pungo, Plymouth, Seneca, B 56-11, B 400-1, 627-164, B 926-9, B 929-6, B 962-3, B 1270-7, B 2131-3, B 2162-18, B 2340-2, and many other related seedling varieties.

Verticillium Wilt. Verticillium wilt, caused by a soil- and seed-borne fungus, is an old disease of potatoes. It has been called the "die early" disease in the Pacific Northwest. It has caused much damage in certain districts of Idaho, Washington, Oregon, and California, and recently it has caused serious losses in some fields in Maine. Several varieties of potato have shown resistance, but so far none shows immunity. Among the resistant named and numbered varieties are Sequoia, Houma, Menominee, Ontario, Saranac, Populaire, 41956, A1-10, A104-1, A129-1, B 137-5, A143-8, 792-88, 792-94, B 1268-26, A144-1, B 3191-4, B 3195-3, B 3199-19 and a number of other varieties.

Wart. Wart is an important disease in most countries of western Europe. It was discovered in some of the mining villages of Pennsylvania in 1918 and later in similar districts of Maryland and West Virginia. Its spread has been controlled by strict regulations governing the importation of potatoes from foreign countries, by the growing of immune varieties, and by the laws prohibiting the shipment of potatoes out of infested areas. Over a period of years tests of new varieties and seedlings were conducted in Pennsylvania. Katahdin, Mohawk, Sequoia, Mesba, and Norkota showed an immune reaction. Of 60 other seedling varieties tested 11 were immune, 4 very resistant, and 45 susceptible. About 50 per cent of a selfed line of Katahdin was highly resistant to wart. The wart tests have been discontinued as all wart-infested experimental areas in Pennsylvania were chemically treated to destroy the remaining wart organisms.

Corky Ringspot. Corky ringspot was first observed at Hastings, Florida, in 1946. Since then observations show that it varies in intensity from one season to the next in the same fields. In 1953 about 49 per cent of the tubers of Sebago were affected in one section of the Potato Investigations Laboratory farm; in 1954 only 5 per cent of the tubers on the same field were infected. Named and numbered varieties that escaped infection for 4 years when grown on infested soil are Merrimack, Plymouth, B 294-65, B 381-2, B 595-76, B 606-3, B 721-1, and B 926-6.

Ring Rot. Ring rot has been considered a menace to potato growing wherever it is found. By 1940 it was found in 37 States, and in some instances the losses from its inroads were very great. It has been held in check by enforcing a zero tolerance for certified seed and by taking all other precautionary sanitary measures. Named and numbered varieties highly resistant to ring rot and possessing the capacity to produce good yields of high-quality potatoes are Merrimack, Saranac, Teton, B 721-29, B 919-28, B 922-8, B 991-14, B 2117-2, B 2787-1, and B 2854-1. Numerous other seedling varieties show a high degree of resistance.

Southern Bacterial Wilt. Southern bacterial wilt, known also as bacterial wilt and brown rot, occurs in warm regions throughout the world. The bacteria causing this disease are seed- and soil-borne, but most of the disease is caused by the soil-borne bacteria. Katahdin and Sebago are less susceptible than other commonly grown varieties, but their degree of resistance is of little or no value on heavily infested soils. However, Sebago has solved the brown rot problem for many of the growers in the Hastings district of Florida. Recent tests by R. E. Webb indicate that the varieties Early Gem, Saco, and Sequoia are more resistant than Sebago.

Hopperburn. In breeding for resistance to hopperburn it was found that a number of seedling varieties are more resistant than any of the old commercial sorts. Sequoia was released because of its resistance to hopperburn, and although in recent years much work has been done on breeding for resistance, Sequoia is still the outstanding commercial variety in its resistance to leaf hopper injury. Seedling varieties resistant to hopperburn are OB 2905-1, OB 3022-1, OB 3363-1, OB 3421-2, OB 3477-2, OB 3672-1, OB 3672-2, OB 3672-4, and a number of others.

Aphid Injury. Some varieties like Katahdin are very susceptible to aphid injury, but a number of seedling varieties are highly resistant. Some of the varieties that appear to be resistant to leaf roll may have resistance because they are resistant to aphids that are the vectors of the leaf-roll virus. Seedling varieties resistant to aphid injury are B 294-38, B 294-85, and a few other related seedlings.

Multiple Resistance

Varieties have been produced possessing a high degree of resistance to 2, 3, 4, and 5 major diseases. The named varieties resistant to several diseases and the diseases to which they are resistant are given in table 2.

Discussion

No variety that will meet the needs of the growers in all the cooperating States has been released, and it is doubtful whether such an ideal variety

TABLE 2.—*Some of the named varieties possessing multiple resistance and the diseases to which they are resistant.*

Resistant Variety	Diseases
Cherokee	Mild mosaic, net necrosis, scab, and late blight
Houma	Mild mosaic, net necrosis, leaf roll, and verticillium wilt.
Katahdin	Mild mosaic, net necrosis, and leaf roll (weak resistance).
Chippewa	Mild mosaic, and net necrosis.
Kennebec	Mild mosaic, net necrosis, and late blight.
Menominee	Scab, late blight, and verticillium wilt.
Merrimack	Mild mosaic, net necrosis, late blight, and ring rot.
Ontario	Late blight, scab, and verticillium wilt.
Saco	Latent mosaic, mild mosaic, rugose mosaic, net necrosis, and late blight.
Sebago	Mild mosaic, late blight, yellow dwarf, and brown rot.
Saranac	Late blight, ring rot, and verticillium wilt.
Plymouth	Late blight, and scab (moderate resistance).
Sequoia	Late blight in vines but not in tubers; hopperburn.
Pungo	Late blight, and scab (moderate resistance).

will be produced in the near future. There has been, however, a State or a sectional demand for each of the new varieties; some of them have steadily increased in importance in severe competition and with very critical evaluation, because of special characters that give them a distinct advantage over the old standard varieties. Some varieties, such as Sequoia and Early Gem, were released to meet a special need and are not adapted to a wide range of conditions. Other varieties such as Katahdin and Sebago are widely adapted.

New varieties are released jointly by the United States Department of Agriculture and one or more State Agricultural Experiment Stations after these have been given extensive tests in the State or States that sponsor the release. The national policy, in naming and releasing new varieties of any crop, prepared by a committee of representatives of the United States Department of Agriculture and of directors of State agricultural experiment stations, has always been adhered to. This policy states as its first requisite: "No new variety should be released unless it is distinctly superior to existing commercial varieties in some one or more characteristics important for the crop and is at least satisfactory in other major requirements." If this policy is adhered to, and it should be, it will become increasingly difficult to breed varieties that can be released. However, the results that have been accomplished and the array of characters that are now available in cultivated varieties and in wild species promise much for the potato-breeding program of the future and for the production of new varieties more outstanding than any that are now available.

SUMMARY

Potato breeding in the United States began about 100 years ago to produce varieties that would not become infected with the late blight fungus. Many varieties were produced by growers and amateur breeders but none was resistant to the fungus. In 1910 the United States Department

of Agriculture undertook to breed blight-resistant varieties but soon changed the program to breed for resistance to virus diseases and did that with remarkable success. In 1929 the National Potato-Breeding Program was organized cooperatively between the United States Department of Agriculture and interested State agricultural experiment stations. At present 39 states and 3 territories are cooperating, and informal cooperation is carried on with a number of foreign countries. Most of the work has been with foreign and domestic varieties of *Solanum tuberosum*, but species and species hybrids also have been investigated. Many characters have been isolated from *S. tuberosum*, and a most important one, immunity from several races of the late blight fungus, has been isolated from *S. demissum*.

In 1954, 62 per cent of all the certified seed grown in the United States originated from the 35 varieties released since the organization of the National Potato-Breeding Program. We have released varieties resistant to the following diseases and have many others in each category maintained for breeding purposes or future release: mild mosaic, latent mosaic, veinbanding mosaic, rugose mosaic, yellow dwarf, leaf roll, net necrosis, late blight, dry rot, caused by the late blight fungus, early blight, common scab, verticillium wilt, wart, ring rot, and hopperburn. We have released several varieties with multiple resistance, for example, Saco is resistant to mild mosaic, latent mosaic, rugose mosaic, net necrosis, and late blight. Judging from results and the great number of major characters available in cultivated varieties and in the wild species, the varieties of the future should be more valuable than any that are now available.

FOLIAGE FUNGICIDES FOR POTATOES IN IOWA[1]

W. J. Hooker[2]

Potatoes, grown principally on the peat soils in northern Iowa, are the most important vegetable crop of the state. Spraying for the control of early blight (*Alternaria solani* (Ell. & G. Martin) L. R. Jones & Grout) and late blight (*Phytophthora infestans* (Mont.) de Bary) has long been practiced by virtually all growers in the state. Following the development of certain new organic fungicides it became desirable to compare these with the copper-containing fungicides formerly in common usage. This is a report of results obtained in Iowa peat-land potato fields from 1946 to 1952, of which a preliminary report of work from 1946-1949, has been published (1).

Cobbler potatoes were grown in field trials replicated 4 to 6 times in a randomized block arrangement on peat soils in northern Iowa. The smallest plots were generally 3 or more rows of which the center rows were used for yield and defoliation records. Yield figures are based on the weight of sound tubers passing over a 1⅞ inch screen.

Plants were sprayed at regular intervals by a hand boom connected with a pressure hose to a power sprayer. In early trials, a Hudson "Defender" power sprayer was used with a single nozzle boom. After 1948 a Bean 4A sprayer was operated under pressures of 350-400 pounds per square inch with a 3 nozzle boom.

All plots including the untreated control were sprayed for leaf hopper control with 2 pounds of 50 per cent wettable DDT (trichloro dichlorophenyl ethane) per 100 gallons of spray material. Thorough vine coverage was assured by spraying the plants as the operator walked through the plot in one direction and by spraying plants from the opposite direction as he returned.

Early blight and late blight (Figure 1) were generally present during the trials. Early blight characterized by target-like markings within irregularly shaped lesions generally developed toward the end of the growing season. In certain respects it is an old age disease developing in severity first on leaves of early maturing varieties. In extremely late varieties, early blight may either be absent or only slight in severity even up to frost. In the unsprayed plots at the end of the season, early blight was moderate to severe on the Cobbler variety in 1946, 1947, and 1948. It was of secondary importance when late blight killed the vines by mid-August as was the case in 1950, 1951, and 1952. It was so hot and dry in 1949 that early blight was of negligible importance. Although certain fungicides were relatively effective in delaying early blight, the disease was generally present as the vines matured.

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FIGURE 1.—Typical lesions of A, early blight; and B, late blight, on potato leaves. Photographs by R. E. Wicklund.

Late blight which generally develops rapidly following periods of wet cool weather is characterized by rapidly expanding dark brown to black lesions on leaves, petioles, and stems. The fungus produces spores on the surface of the lesion as a sparse white mold-like growth. Leaf lesions often expand so rapidly that there may be a margin of yellowish green tissue between the healthy leaf tissue and the necrotic area in the center of the lesion. Late blight was very severe in 1950, 1951, and 1952 killing the unsprayed controls by the middle of August. The disease was absent in 1946 and 1947, scattered and moderate in the plots in 1948, and, although present, was virtually held in check by the hot weather in 1949.

Copper containing fungicides, (Table 1) were selected as typical of those commonly employed in commercial practice. Of the zineb group of organics a representative commercial product was selected as being typical and used throughout. A limited attempt was made to evaluate other zineb products and performance of the various compounds was generally similar. A few other fungicides were tested for a year or two but dropped because of lack of promise. Data from these are not presented.

The extent of defoliation during each season (Table 2) was determined using the method of Horsfall and Barratt (2), and seasonal defoliation for 1951, a year in which late blight was very severe, is presented in figure 2. Defoliation every year was most severe in the control plots receiving only DDT. In 1948, 1949, and 1950 differences were relatively small in the degree of control obtained with the various fungicides tested. In these years, late blight was not severe. Greater differences were obtained between fungicides in 1951 and 1952 when late blight was severe.

Yield response (Table 1) to Bordeaux mixture was variable with yields being higher than the untreated control in 5 of the 7 years and in no instance were they significantly lower than those of the unsprayed plots. Injury of the top leaves with Bordeaux was observed occasionally when bright sunlight and high temperature followed periods of low temperatures and heavy rains. When Bordeaux spray was applied regularly there was some evidence of a depressing influence on yield as in 1948, 1949, and 1952. In these years foliage protection with Bordeaux mixture was approximately equal to that with certain other fungicides. In contrast, yields with Bordeaux were not so high as those obtained with these other fungicides. In 1952, Bordeaux mixture was compared with zineb at 7 and 14-day intervals. Yields with Bordeaux were higher but not significantly higher at 14 than at 7-day intervals whereas the reverse obtained with zineb.

The possible influence of minor essential elements, particularly manganese, on yield was suggested by results in 1949. Hoyman (3) has reported responses in North Dakota from zinc contained in certain fungicides. In the Iowa trials in 1949, yields from maneb-sprayed plots were significantly higher than those from any other treatment whereas both early blight and late blight were of minor importance during the season. The importance of manganese and zinc as minor essential nutritional elements was evaluated the same year in plots adjacent to the fungicide plots. A significant response was obtained to manganese as a soil treatment in combination with sulfur. No response was obtained with neutral manganese and zinc as foliage sprays. In 1950 and 1952, in similar

TABLE 1.—*Yield of Cobbler potatoes sprayed with a number of foliage protectants.*

Fungicide name	Amount /100 gal.[1]	Yields of Tubers over $1\frac{7}{8}$" Diameter							
		1946	1947	1948	1949	1950	1951	1952a[2]	1952b[2]
		Bu./A.	Bu./A.	Bu./A.	Bu./A.	Bu./A.	Bu./A.	Bu./A.	Bu./A.
None		278	121	312	300	371	129	430	430
Bordeaux mixture: $CuSO_4$	8 lbs.	334*	112	378*	280	387	217*	512*	538*
lime	4 lbs.								
Tri-basic copper sulfate[3]	4 lbs.	295	120	427*†	303	379	215*	648*†	...
Copper zinc chromate[4]	2 lbs.	...	...	406*	308	444	172	...	...
Ziram[5]	2 lbs.	336*	122	402*	...	...	...	...	...
Zineb[6]: nabam	2 qts.	351*	141†	429*†	302	426	301*†	601*†	566*
$ZnSO_4$	1 lb.								
Maneb[7]	2 lbs.	...	...	427*†	380*†	445	322*†	670*†	...
Minimum significant difference, 5 per cent level		43	22	38	42	NS	75	86	86

*Significantly better than untreated control at the 5 per cent level.
†Significantly better than Bordeaux mixture at the 5 per cent level.
[1]All plots sprayed with 2 pounds of 50 per cent wettable DDT (trichloro dichlorophenyl ethane) per 100 gallons.
[2]1952a, plots sprayed at 7 day intervals, and 1942b, plots sprayed at 14 day intervals.
[3]Tri-basic coppuer sulfate ($CuSO_4$: 3 $Cu(OH)_2$) 98 per cent : Cu 53 per cent. Trade name, Micronized Tribasic Copper, Tennessee Copper Corporation.
[4]Copper zinc chromate (15 CuO : 10 ZnO : 6 CrO_2 : 25 H_2O) 95 per cent; copper 29.6 per cent, zinc 20.4 per cent, and chromium 9.7 per cent. Trade name, Crag Potato Fungicide 658 blend A, Carbide and Carbon Chemicals Company.
[5]Zinc dimethyldithiocarbamate 76 per cent. Trade name, Zerlate, Grasselli Chemicals Depratment, E. I. duPont de Nemours and Co. (Inc.)
[6]Zinc ethylene bisdithiocarbamate prepared by mixing 2 quarts nabam (disodium ethylene bisdithiocarbamate hexahyrate) 27 per cent with 1 pound zinc sulfate per 100 gallons. Trade nmae of nabam, Dithane D14, Rohm and Haas Co.
[7]Manganous ethylene bisdithiocarbamate 70 per cent. Trade name, Manzate, Grasselli Chemicals Department, E. I. duPont de Nemours and Co. (Inc.)

TABLE 2.—*Defoliation of Cobbler potatoes sprayed with a number of foliage protectants.*

Fungicide[1]	Defoliation on Dates Indicated[2]							
	1946 8/24	1947 8/26	1948 8/12	1949 8/15	1950 8/24	1951 8/29	1952a 9/4	1952b 9/4
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
None	97	65	81	34	99	99	100	100
Bordeaux mixture	84	33	49	16	30	53	36	25
Tri-basic copper sulfate	93	56	49	21	35	86	30	...
Copper zinc chromate	...		43	14	27	96	...	...
Ziram	81	31	56	...	...	...		
Zineb	70	26	43	9	35	35	19	19
Maneb	...	...	43	11	20	18	27	...

[1]For details concerning fungicide see table 1.

[2]Details of disease appearance and methods of application are given below.

1946 5 sprays 6/28-8/31 at approximately 16-day intervals. Crystal Lake, Iowa.
Late blight—absent. Early blight—moderate on 8/13 and severe by 8/24.
Season—rainfall below normal, temperatures below normal.

1947 4 sprays 7/15-8/30 at approximately 15 day intervals. Fields too wet for additional sprays. Crystal Lake, Iowa.
Late blight—absent. Early blight—severe by 8/26.
Season—border line flood conditions in July and August, temperatures above normal.

1948 7 sprays, 6/25-8/24 at approximately 10-day intervals. Crystal Lake, Iowa.
Late blight—scattered 7/19, moderate 8/18. Early blight—moderate 8/18.
Season—rainfall below normal in July and September, above normal in June and August; temperatures, normal or below.

1949 7 sprays, 6/9-8/15 at approximately 10 day intervals. Clear Lake, Iowa.
Late blight—scattered 7/25-8/15 held in check by hot dry weather. Early blight—scattered and slight.
Season—August, very hot and dry which reduced spread of both early blight and late blight.

1950 7 sprays 6/29-8/25 at approximately 10-day intervals. Clear Lake, Iowa.
Late blight—moderate 8/15. Early blight—minor importance.
Season—rainfall above normal; temperatures, cool.

1951 9 sprays 7/18-9/14 at approximately 7-day intervals. Garner, Iowa.
Late blight—severe. Early blight—minor importance.
Season—rainfall abnormally heavy; temperatures, very cool.

1952a 10 sprays 6/24-8/30 at approximately 7-day intervals. Clear Lake, Iowa.
Late blight—first appeared 8/4, severe by 8/12. Early blight—late August moderate on sprayed plots.
Season—rainfall above normal; temperature, cool evenings, hot days.

1952b 6 sprays 6/24-8/30 at approximately 14-day intervals. Clear Lake, Iowa.

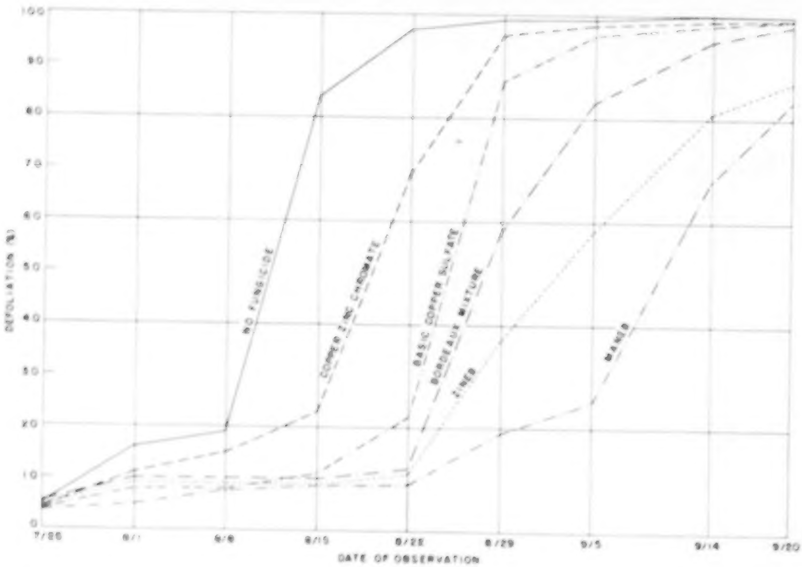

FIGURE 2.—Relative defoliation rates of the Cobbler variety when protected by various fungicides. Observations were made in 1951 when late blight was severe.

trials, no further manganese or zinc response was obtained. For these reasons yield increases resulting from spraying maneb and zineb in years other than 1949 are believed to be due, in major part, to fungicidal protection.

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PHYSIOLOGIC RACES OF LATE BLIGHT FUNGUS FROM POTATO DUMP-HEAP PLANTS IN MAINE IN 1955[1]

R. E. WEBB[2] AND REINER BONDE[2]

The potato-growing season of 1954 was one of the worst blight ones on record for Aroostook County, Maine. Cool cloudy weather with frequent showers provided ideal conditions for infection of potato plants and sporulation and dissemination of the pathogen during the entire season. Consequently, there was some infection in most if not all potato fields despite an intensive spray control program. In several fields of the variety Kennebec, which is highly resistant to, if not immune from, the common race (race 0) of the blight fungus, there was slight to moderate infection by early July. This indicated that a physiologic race or probably races (1) of the organism more virulent than the common race were present early in the season. In 1954 early outbreaks of blight in widely separated fields of Kennebec potatoes indicated a survival of the causal fungus in tubers of this variety which had become infected in 1953. Field inspections at harvest showed some tuber infection of blight-resistant varieties such as Kennebec, Cherokee, and Pungo. Many of the diseased tubers were discarded on potato refuse piles after grading operations. Infected volunteer plants from the diseased tubers probably provided an early source of inoculum (3) more virulent than that of the common race in 1955. A survey of potato-refuse heaps was initiated in June 1955 to determine the prevalence of the Kennebec race (race 1, International System) and other physiologic races of *Phytophthora infestans* (Mont.) DBy which might be sources of primary inoculum.

MATERIALS AND METHODS

An extensive survey of the potato refuse piles in Aroostook County was made June 5 and 6, 1955, by Hyre and Bonde (5), and 6 individual samples of infected plants were collected. On June 22 and 24 the senior author visited 19 dumps in eastern and northern Aroostook County and collected 9 additional samples of diseased plants. The samples of infected material were placed overnight in individual moist chambers for sporulation. The spores were then washed from the leaves and stems and kept at 58° F. to induce zoospore germination. Detached leaves from differential hosts[3] (table 1) held in moist chambers were used for race identification. A wooden flat 3" x 15" x 23", covered with a 16" x 24" glass pane, served as the moist chamber. Wet burlap was placed in the bottom of the flat and covered with moist paper toweling. A tagged leaf, 5 to 7 leaflets, from each differential host was placed bottom surface up on the moist paper toweling in each flat. A zoospore suspension from each sample was atomized on the detached leaves in 1 to 3 moist chambers depending on the available inoculum. The inoculated leaves were held at room temperature (approximately 70° F.) for 24 hours and then placed in the potato storage house at a temperature of 56° to 60° for 7 to 10

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[3]Supplied by the Inter-regional Potato Introduction Station, Sturgeon Bay, Wis.

TABLE 1.—*The occurrence of different physiologic races of Phytophthora infestans on plants of 15 potato refuse heaps.*

Host	Genotype	Race Designation	Frequency of Each Race
Green Mountain	r	0	1
Essex	R_1	1	3
3 RC-8	R_2	2	3
1253a (12)	R_3	3	5
DXD-3	R_4	4	1
3 XE-1	R_1R_2	1,2	6
4739-58	R_1R_3	1,3	5
3 WM-19	R_1R_4	1,4	10
1682C (1)	R_2R_3	2,3	0
TI5	R_2R_4	2,4	8
1488b (1)	R_3R_4	3,4	8
3 XX-1	$R_1R_2R_4$	1,2,4	6
Kennebec			11[1]

*Kennebec was inoculated with zoospores from each sample to determine the percentage of infected samples yielding a race that was pathogenic to this variety.

days. The source of light was 100-watt Mazda light bulbs suspended from the ceiling. Subinoculations to the differential hosts were made from the inoculated Green Mountain leaves when the original inoculum was sufficient for only one flat. Sporulation of the pathogen on the highest host range level, *i.e.*, R_1; R_1,R_2; R_1,R_4; and R_1,R_2,R_4, was the basis for race identification. Subculturing from the higher host range levels, *i.e.*, R_1,R_4; R_1,R_2,R_4, to the single-gene hosts or the complete set of differentials gave conflicting results.

RESULTS

Table 1 summarizes the number of times each race was identified from the late blight samples collected from 15 widely separated potato-dump heaps. The common race (0) alone was recovered from only 1 infected sample collected from a few infected plants of Katahdin on a small dump. One race each was identified from 4 samples, whereas the other 10 samples contained 2 or more specialized races as mixtures. Eleven of the samples contained one or more races pathogenic to the variety Kennebec.

Fourteen samples were collected from infected plants of the blight-susceptible varieties Cobbler, Green Mountain, and Katahdin, and one sample was collected from diseased plants of Kennebec. At the time of collection most of the infected areas occurred on the lower stems and only a few leaves showed lesions. This indicated that the infection had originated in the tubers. Apparently, under the ideal environmental conditions for a blight epidemic which existed during 1954, the specialized races developed on inadequately sprayed resistant varieties became established on varieties carrying no resistance to blight, and were carried overwinter in infected tubers of both resistant and non-resistant varieties. Howatt and Grainger (4) presented evidence that a specialized race may develop on the susceptible variety Green Mountain. Similar results obtained

in this study indicate that under the favorable conditions of 1954 specialized races may have developed on non-resistant varieties and were carried over-winter in the tubers.

A survey conducted in Aroostook County, Maine, in 1954 (2), generally showed that Kennebec withstood the late blight epidemic better than Katahdin and other susceptible varieties; however, some fields of Kennebec were severely damaged. Blight infection was observed in small plantings of Pungo, Cherokee, and Saco, which are highly resistant to race 0. These studies indicate that specialized races of the late blight fungus are prevalent in Aroostook County and are capable of causing serious damage to potato varieties highly resistant to race 0. Consequently, such varieties should be adequately sprayed wtih a fungicide to prevent plant and tuber infection. Stevenson *et al.* (6) obtained better yields and higher dry matter from highly resistant varieties when sprayed with copper than when sprayed with only water under a severe epidemic of late blight.

Summary

Samples of the late blight fungus were obtained from infected plants growing on 15 potato-dump heaps in Aroostook County, Maine, during June 1955. Inoculation of differential hosts showed the presence of 11 races. Of the 15 samples, 10 were mixtures of 2 or more races. Race 0 alone was identified in only one sample. Races of the blight fungus pathogenic to Kennebec were found on 11 of the 15, or 73.3 per cent, of the refuse heaps. Consequently, Kennebec and other named varieties highly resistant to, or immune from, race 0 only should be adequately sprayed with a fungicide.

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CONTROL OF POTATO BLACKLEG WITH ANTIBIOTICS[1]

D. B. ROBINSON[2] AND R. R. HURST[3]

INTRODUCTION

The organism, *Erwinia atroseptica* (van Hall) Jennison, is responsible for important losses in potato production by causing seed-piece decay and blackleg. Studies in Maine (1, 2), carried out chiefly in the greenhouse, have shown that some antibiotics having a streptomycin base are effective in reducing the severity of the disease in both its phases.

The purpose of this paper is to report the results of some field trials on the control of potato blackleg with antibiotics conducted in Prince Edward Island. Studies were made on the control given by seed-piece treatment and also on the effect of antibiotic foliar sprays.

TREATMENT OF SEED PIECES

All seed-piece treatments were carried out by immersing the cut seed in the appropriate solution after first inoculating with blackleg bacteria. Inoculation was done by immersing the sets in two-day old nutrient broth cultures of *E. atroseptica* diluted to six times their volume. The variety Sebago was used in all trials.

Two experiments were conducted on seed treatment. In the first the antibiotics Agristrep[4] and neomycin sulfate[4] were used, and in the second the commercial preparations Agristrep[4], Agri-mycin 100[5] and AS-15 Agricultural Streptomycin[5]. Agristrep and AS-15 Agricultural Streptomycin contain streptomycin as the active ingredient; and Agri-mycin 100 contains both streptomycin and oxytetracycline (terramycin). In each experiment one lot of seed was treated with Semesan Bel and one lot left untreated as a check. Treatment with the organic mercury Semesan Bel was included for comparison, because it is often used commercially as a protectant against tuber-borne potato diseases.

Following inoculation and treatment the seed pieces were air dried and planted in randomized block designs. Blackleg began to appear soon after the plants emerged and continued to develop over a period of six weeks from the date of planting. The treatments used and the results in emergence and percentage of blackleg development are given in table 1. All the treatments with antibiotics in which streptomycin was the active ingredient gave almost complete control of blackleg in both years of testing. Neomycin sulfate was of no value, and Semesan Bel gave only partial protection. With a solution containing 100 p.p.m. streptomycin, an instant dip was apparently as effective as soaking for longer periods. The antibiotic treatments markedly improved plant vigor in comparison with no treatment or treatment with Semesan Bel.

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[4]Products of Merck & Co. Ltd., Montreal, Que.
[5]Products of Chas. Pfizer & Co. Inc., Brooklyn, N. Y.

TABLE 1.—*The effect of seed-piece treatment with some antibiotics on emergence and on blackleg.*

Seed Treatment Antibiotic[1]	Period of Immersion of Cut seed	Percentage Non-emergence	Percentage Blackleg
EXPERIMENT I[2] — 1954			
Agristrep	10 minutes	3.0	3.0
Neomycin sulfate	10 minutes	5.0	14.0
Semesan Bel	Instant Dip	3.0	7.0
Check	....	9.0	12.5
EXPERIMENT II[3] — 1955			
Agristrep	Instant Dip	3.0	1.0
Agristrep	15 minutes	2.0	1.0
Agristrep	30 minutes	3.0	0.0
AS-15 Agricultural Streptomycin	Instant Dip	4.0	0.0
Agri-mycin	Instant Dip	6.0	1.0
Semesan Bel	Instant Dip	16.0	1.0
Check	....	34.0	28.5

[1]Antibiotics were used at a concentration of 30 p.p.m. streptomycin in Experiment 1 and at a concentration of 100 p.p.m. streptomycin in Experiment 2.
[2]Data based on 200 seed pieces in each treatment.
[3]Data based on 600 seed pieces in each treatment.

EFFECT OF STREPTOMYCIN AS A FOLIAR SPRAY

The most severe incidences of blackleg in Prince Edward Island originate from infected seed-pieces, but a midseason infection of vines resulting in an upper-stem blackleg is also an important phase of the disease. Vine infections often occur at injured areas and are apparently spread by machinery or insects. An experiment was conducted to determine if a streptomycin spray would give any control of this phase of the disease.

Sebago plants, six weeks old, were sprayed with Agristrep at a concentration equivalent to 100 p.p.m. streptomycin and at a rate of approximately 80 gallons of the solution per acre. Stems were inoculated five days later by the method of inserting hardwood splinters that had been previously soaked in a suspension of blackleg bacteria (see Figure 1). Inoculum consisted of a two-day-old nutrient broth culture of *E. atroseptica*. Blackleg began to appear in five days and disease severity was recorded eight days after inoculation by rating the infections on a scale of 0 to 4 to denote a severity of disease from none to slight, moderate, severe and dead. These ratings were then weighted and calculated as a percentage index. The results, given in table 2, show that the foliar application of Agristrep significantly reduced the severity of disease. This effect was evidenced by the smaller lesions on sprayed plants rather than by an absence of infection.

FIGURE 1.—Method of stem inoculation. Hardwood splinter soaked in bacterial suspension before insertion.

TABLE 2.—*The effect of streptomycin (Agristrep), used as a foliar spray, on subsequent blackleg development.*

Treatment	Disease Index[1]	Converted Indexes[2]
Sprayed—100 p.p.m. streptomycin	19.8	25.6
Unsprayed check	43.7	41.1
N.D.S. at P — 0.05		7.8

[1]Data from a total of 330 inoculated plants in a seven-replicated test.
[2]Angle transformation of percentages.

FIGURE 2.—Control of seed-piece decay and blackleg with an antibiotic in a 3-row plot. Left: Inoculated seed-pieces dipped in Agristrep (100 p.p.m. Streptomycin) before planting. Right: Inoculated seed-pieces—untreated.

DISCUSSION

The results obtained in these field trials support the conclusions of others (1, 2) that treating cut seed potatoes in antibiotics containing streptomycin will reduce losses caused by the blackleg organism *E. atroseptica*. Besides lessening the incidence of blackleg, the treatments reduced bacterial seed-piece decay and improved plant vigor.

Limited experimental evidence indicates that an antibiotic foliar spray is effective in reducing the severity of subsequent blackleg infection. Absorption and translocation of the active ingredient within the plant is a possible explanation of this, as has been found in work with bacterial blights of bean (3).

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RECENT DEVELOPMENTS IN POTATO RESEARCH IN THE UNITED STATES[1]

ORA SMITH[2]

With your permission I shall first present a brief review of what potato production in our country consists of and how widespread it is. Recently we have produced from 350 to 400 million bushels a year. That includes every state in our country although some states are deficient in production, that is, they don't produce as many potatoes as the people in those states will eat.

Although 48 states produce potatoes there are 5 which produce over one-half of our supply. Maine has been first for many years, Idaho, second; California, third; New York, fourth; and North Dakota fifth; in 1954.

Each month, beginning in July, the U.S.D.A. estimates the production for that year. They have already made their first prediction on July 1st of this year and a little more than 400 million bushels are predicted for 1955, that is, more potatoes than we can consume in any normal manner. We consume in our country about 345 million bushels of potatoes a year. The estimate, as I have just mentioned, is for 55 million bushels more than we'll know very well what to do with.

We do not, as many of you know, plant potatoes in our country with the expectation of making starch or alcohol out of them or feeding them to livestock. Those industries get only culls or a better grade if we have tremendous over-production.

Unless our present drought, which prevails in a part of our country, will last considerably longer this season, we will have a surplus production. Our average production this year is predicted as 277 bushels per acre. That sounds very low to some of you and yet if we reach that figure, it will be the highest acreage yield that we've ever attained. It is not a remarkably high yield, but when you consider that 25 years ago the average yield for our country was less than one-half of that amount, you can see that considerable progress has been made in increasing our production.

Our acreage this year is 1,444,000. We have had a little bit less than that, but not much. This is less than one-half the acreage that we had 25 years ago, so that it means a large part of this increase in production per acre is due to dropping out the marginal land that should not have been devoted to potato production under normal conditions. Some, of course, has naturally been caused by better methods of production.

We have just leveled off our annual *per capita* consumption of potatoes. For many years it has been going down and it is now about 104 pounds a person per year. This sounds very small to all of you people in this part of the world and it is. It seems low to me and I would

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This is a brief report of a recording of the informal presentation made on August 8, 1955 at the Third Meeting of the Northwest Europe Potato Conference August 8-11, 1955. Wegeningen, The Netherlands.
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much rather have it higher than that. It has been a little bit lower, but in recent years, consumption has leveled off and increased slightly. Not many of us, however, have hopes of bringing the consumption figure up very much above what it is. We have, I suppose, too many foods competing with potatoes to bring this about.

We consume about the same number of pounds of food per year as we did some years ago. But the type of food that we eat has changed considerably. We have so many foods now, frozen foods, foods that are prepared fresh—all prepared for the table, for immediate use. Our potatoes must be competitive with them; if they are not, there will be further decreases in consumption of potatoes in our country. I think that is the biggest single reason why our consumption has declined. But some of the reduction in consumption of potatoes in our country has also been due to the poor cooking quality of potatoes which are offered to our consumers.

There are more than 350 projects in progress at the State and Federal Experiment Stations in the United States covering the entire field of potato production, storage, processing, grading, packing, packaging, shipping, *etc.* I have broken these down into a number of different groupings. One of the big groups is potato breeding and the testing of varieties and seedlings.

Breeding and Testing Varieties and Seedlings

Many of you know that for 25 years we have had a National Potato Breeding program in our country, which is directed by the U.S.D.A.

This program works cooperatively with approximately 30 states in our country. Much of the breeding work in done by the U.S.D.A. personnel stationed in Maine. The seedlings developed are sent to a number of states for trial. If they prove worthy of commercial adoption, they are named and offered for multiplication.

They are breeding for most of the things that the plant breeders in this section of Europe are breeding for: high yield, resistance to early blight, late blight and scab, Verticillium wilt, black spot, leafroll, the mosaics, bacterial ring rot, golden nematode, *etc.*

I know of 55 projects on potato breeding and testing varieties and seedlings and about 9 projects on the source and quality of seed, size of seed pieces and distance of spacing. As new varieties are produced, it is necessary to find out how those varieties react to the size of seed pieces planted, how close they should be planted in the row, how they react to irrigation, spray programs and many other things. One can't assume that a new variety is going to react in the same way that an older variety has reacted. There also are differences in response of some of the new varieties to different fertilizer applications.

Rotations, Cover Crops and Organic Matter

There are 10 projects which have to do with potato rotations, cover crops, green manure crops, and that sort of thing.

Since our acreage is decreasing, we are becoming more and more specialized in growing potatoes.

Most of the potatoes produced in upstate New York 25 years ago were grown by people who primarily were dairymen interested mainly in producing milk. Now they are predominantly potato growers who specialize in this crop. Their operations are completely mechanized and they use shorter rotations. The problem of maintaining organic matter in the soil under these conditions is intensified.

Potato Fertilization

On potato fertilization there are 23 projects, concerning rate of application of fertilizer, source of potash, source of nitrogen, time of application of the fertilizer and so on. We are now getting into new nitrogen carriers, the ammonias and the liquid nitrogens and doing some work with the application of the urea form of nitrogen as a spray to the plants in the field.

In addition we have to keep a certain number of the old standard fertilizer experiments in progress, because occasionally we will find an area that has just recently developed a deficiency of magnesium in our soils, which did not exist there previously. There are a few areas where zinc is deficient or copper and boron.

Cultural Conditions and Irrigation

There are several projects on cultural conditions, date of planting and planting depth. There are 10 projects on irrigation. In the West where they have been irrigating potatoes for many years, they are studying rate of penetration of moisture through different types of soils and quality of the water applied. In the East where we supplement our rainfall of 35-38 inches a year, studies include amount and time of irrigation, effect on fertilizers, tuber set, size of tubers, yields, quality, *etc.*

Chemical Weed Control

We are still working with chemical weed control, controlling weeds in potatoes with pre-emergence applications of the dinitros. A few states are suggesting the use of 2,4-D. Post emergence application of 2,4-D or the dinitros also is successful if directional application is made to the base of the plant.

Nematodes

There are five projects on nematodes. As far as we know, the only place where the golden nematode exists in our country is on Long Island. New York State has two or three projects on that subject. The potato rot nematode, the Ditylenchus, which exists in Wisconsin, Idaho and California, is the subject of the other projects on the nematode. They are studying the effects of irrigation, rotation, varieties, the breeding for resistance and biochemical studies of leachings from the roots of the potato and tomato plants. This is similar work to some that is being done in Europe.

Potato Diseases and Their Control

There are 67 projects on potato diseases and their control. This is in addition to control by breeding methods. A number of these projects are on newer methods of getting fungicides on the plant. Row crop airblast sprayers and low gallonage spraying are being studied. They hope to obtain control of late blight and other diseases but by the use of considerably less water. Many of our potato fields are on hill tops and water is difficult to get and must be transported long distances. Dusting has never been quite as satisfactory with us as spraying for late blight control.

Potato Insects and Their Control

There are 25 projects on potato insects and their control and as you well know, this development has progressed very rapidly in the last 10 years since the advent of DDT. Our method of growing potatoes has been revolutionized since the widescale use of DDT. It is one of the best things that has ever been found, and on the other hand, it has been one of the worst things to happen as far as cooking quality is concerned. Spraying and dusting for control of foliage insects and soil treatments for wireworm control lead the list of insect control projects.

Sprout Inhibition

We have about seven projects in our country that I could find on sprout inhibitors and plant growth regulators. Research workers are attempting to volatilize methyl ester of naphthaleneacetic acid in the storage, blow it through the regular ventilation channels up through the pile and treat potatoes in place. Anything which is going to involve an extra handling of potatoes I don't think will ever get very far or will be accepted very widely. Many growers don't know, as potatoes go into storage, whether they are going to use them for seed or for table stock. They don't have the sharp line of demarcation that you have here and out of the same bin they may take some of the real large potatoes and sell them for table stock and use the medium and small sizes for seed. Therefore, there are times when we dare not treat with maleic hydrazide in the field as we would like to do. Maleic hydrazide, when sprayed on foliage in the field, is translocated to the tuber and creates a certain degree of dormancy in the potato. That method of application is now fairly widely accepted and used by people who are in the potato chip business or farmers who are growing potatoes, expecting to sell them to the chip processor. More recently there has been work with the irradiation of potatoes with various types of rays. Irradiated cobalt, a waste product from atomic fission research, does a wonderful job of suppressing sprout growth. We know very little beyond that as to what it does to the potatoes. It is difficult to irradiate without an extra handling of the potatoes and this may be a handicap to the use of that method of sprout inhibition even though the process might be brought down to a reasonable cost.

There is also some work being done with mixing methyl ester of naphthaleneacetic acid in the wax where potatoes are washed and then waxed. This work is confined largely to the Red River Valley. It seems

to do a good job of reducing the amount of sprout growth in potatoes. Waxing alone does not help in keeping down sprout growth.

Killing Potato Vines

There are not as many active projects on killing potato vines now as there were some years ago. Practically all of our late potatoes are now killed either by the mechanical type of rotobeater or some variation of it or by spraying with sodium arsenite or some of the dinitro compounds. Some seed growers use a combination of the two. They rotobeat and then kill the existing short stems that are green and could still harbor aphids and *Phytophthora*.

Cause and Prevention of Mechanical Injuries

Every survey that has been made in our country in recent years indicates that mechanical damage is the greatest defect of the potato exterior when they reach the consumer. With our methods of rapid harvesting and our mechanization, it is likely to remain fairly high unless a great deal of study is made to try to reduce that damage. In the Red River Valley they are working with the separation of clods of soil from the potatoes during the digging operations. These clods are very difficult to deal with. In fact, that single thing probably more than any other is keeping potato harvesters down to a relatively low number in some areas. In North Dakota they have a great number of harvesters now, but these clods comprise their greatest difficulty. In other work they are comparing the injuries caused by the regular potato-digger where potatoes are dropped back on the ground, picked up in baskets, barrels or sacks, with injuries resulting from the harvester type which digs and elevates potatoes either directly into bags or into a bulk truck traveling alongside the digger or into pallet boxes of approximately 1-ton capacity. They are comparing the amount of injuries received in all those methods as well as injuries caused by the different ways of getting the potatoes into, and removing them from, storage. Water flumes are compared with elevators and other methods of moving potatoes.

Potato Harvesting, Storage and Handling

Our list shows 19 projects concerned with the above topics. Such topics as the following are being studied: varietal differences and effects of production practices on storage quality; post-harvest physiology of potatoes; air circulation requirements for stored potatoes; improvement of potato harvesting, handling and storage equipment; effects of mechanical injuries on weight loss of potatoes in storage; equipment for filling and removing potatoes from deep bins; combine harvesting methods; potato waxing; costs of harvesting potatoes; effects of stone picking in mechanical harvesting of potatoes and others.

Grading Potatoes by Specific Gravity

There are three projects on grading potatoes by specific gravity separation. Although we have worked with this method for five years, we

don't seem to be making much progress with commercial people who sell and buy potatoes. With this method potatoes are passed through a sodium chloride solution, separating them into two groups, one of relatively low specific gravity, the other of higher specific gravity. This results in a difference in the mealiness of the two lots. They are packaged and marked separately so that the consumer knows what she is getting. The method of making the separation is a problem which we are not much concerned with any more. In our studies we wanted to find out whether the consumer wants that type of service and if she does, whether she is willing to pay for it; and if she will pay for it, how much will she pay. Our five years' results indicate that it costs approximately 30-35 cents per 100 pounds to make this separation followed by washing. We must, of course, wash the sodium chloride solution from the potatoes. Our consumers are evidently willing to pay from $1.00 to $1.50 more per hundred pounds. It seems to be a profitable venture.

Culinary Quality

There are 30 projects on potato cooking quality primarily concerned with texture and color of cooked potatoes. We are working on the premise that after-cooking darkening is a result of the reaction of ferrous iron in the potato and one or more of the orthodiphenols which are in the potato (caffeic acid, chlorogenic acid and others). When the potato is exposed to air, this chemical combination is oxidized from the colorless to the dark form, therefore causing discoloration of the boiled or baked potato. Assuming that this is the mechanism, during the last three years we have utilized a group of chemicals known as sequestering or chelating agents which have the ability to take iron and other metals out of chemical reactions. Our thought was that if we could get these chemicals into the potatoes, and sequester or chelate this iron that darkening would be prevented. Therefore, we sprayed potato plants with a number of the EDTA's (ethylene diamine tetra acetic acid-group) and their Na-salts, Cu-salts, Zn-salts, as well as other salts of the acid. In 1953, it did a very good job of preventing after-cooking darkening. In 1954 we worked with four varieties in a number of locations and with several concentrations and had practically no darkening in anything whether or not it was treated. This method of preventing discoloration looks very promising. This group of chemicals has not yet been accepted by our Food and Drug Administration, however they are used in some foods and, therefore, may be accepted later. There are also a number of other sequestering and chelating agents which we are now testing.

These chemicals also show promise in solving some of the problems of discoloration of commercially pre-peeled potatoes. In our country about four million bushels of potatoes are now peeled in large quantities in commercial plants, treated with sulphur dioxide or sodium bisulphite to keep them from discoloring in the raw state and sold to hotels and restaurants. Small amounts are sold also in retail stores. To prevent after-cooking darkening of peeled potatoes, we have dipped them in a 1 per cent solution of sodium bisulphite and a 1 per cent solution of the sodium salt of EDTA for about a minute. When placed in storage or kept for at

least 24 hours before they are cooked, they will not darken. We have also prevented after-cooking darkening by that method.

We believe there are three types of discoloration in potatoes besides those caused by diseases. One is the discoloration in raw peeled, injured or cut potatoes. And I think that vascular discoloration, which results from vine killing, is also the same type of discoloration.

Another type is the one I've just discussed: after-cooking discoloration, which can not very well be due to enzymatic action at least, not beyond the very first stages.

Factors Affecting Chipping Quality

The third type is a result of the Maillard reaction or the browning reaction, which causes discoloration of potato chips and French fries. Some of the older literature in our country maintains that this discoloration is due to caramelization of sugars. Sugar, however, will not caramelize in two minutes at 188°C., whereas combinations of sugars and amino acids or sugars and ascorbic acid will result in brown discoloration under these conditions.

There are 37 projects listed on potato chip research.

Chemical Composition, Processing and Dehydration

We have 18 projects on potato processing and chemical composition and 6 projects on potato deydration. Such topics as the following are being studied: cell wall components and cementing substances in potatoes and their relation to processing quality; enzyme systems of the potato; organic acids in the potato; chemical methods of paring potatoes; effect of irradiation of potatoes on processing value; varieties and processing value; utilization of waste products of the potato; potatoes in beef stew; recovery of nitrogen compounds from potato starch processing water; study of the amino acids of potatoes; lipids of the potato; manufacture of potato granules and mashed potato flakes and pilot plant studies of these dehydrated products. Methods of preventing discoloration of pre-peeled potatoes and the packaging of this product are also being studied.

Physiology of the Potato

Various phases of respiration and photosynthesis of potato varieties are being studied as well as tuberization and the stimulus resulting in tuber formation.

Potato Marketing

There are 11 projects on potato marketing and 2 on the economics of potato production. I suspect, however, that there are considerably more projects than that on the economics of potato production.

POTATO BREEDERS AND PATHOLOGISTS MEET AT THE UNIVERSITY OF WISCONSIN

R. H. LARSON[1]

On January 16 and 17, 1956, the North Central Potato Breeding Technical Committee, representing nine north central states and the United States Department of Agriculture, met in Madison for a series of scheduled conferences and greenhouse meetings. The conferences covered research projects under way involving new procedures for the development of superior parental lines with special consideration given to disease resistance found in *Solanum tuberosum*, and tuber-bearing *Solanum* species and hybrids. The diseases included: (1) late blight resistance, (2) scab resistance, (3) virus X and virus Y strains in relation to immunity, (4) Verticillium wilt resistance, and (5) tolerance to internal tuber necrosis. Breeding for heat and drought tolerance was emphasized. Problems concerned with the orderly exchange of recently developed breeding lines from State Agricultural Experiment Stations, Vegetable Crops and Plant Introduction Sections of U.S.D.A. and the IR-1 Potato Introduction Project were discussed. The greenhouse meetings were concerned with methods in breeding and testing for disease resistance.

[1]Department of Plant Pathology, University of Wisconsin, Madison 6, Wis.

First row—left to right: N. R. Thompson, Michigan State University; R. W. Hougas, University of Wisconsin; N. K. Ellis, Purdue University; G. H. Rieman, University of Wisconsin; R. W. Samson, Purdue University; R. E. Webb, Beltsville, Maryland, U.S.D.A. Second row—left to right: R. H. Johansen, North Dakota Agricultural College; H. O. Werner, University of Nebraska; R. E. Marshall, Michigan State University; R. H. Larson, University of Wisconsin; C. J. Eide, University of Minnesota; D. C. Cooper, University of Wisconsin. Third row—left to right: A. E. Kehr, Iowa State College; A. E. Schark, Iowa State College; W. N. Brown, Ohio State University; J. P. McCollum, University of Illinois; H. Rex Thomas, Washington, D. C., U.S.D.A.; R. V. Akeley, Beltsville, Maryland, U.S.D.A.; G. S. Pound, University of Wisconsin; D. A. Young, University of Wisconsin; W. J. Hooker, Michigan State University.

ACREAGE-MARKETING GUIDES RECOMMEND 8% REDUCTION IN SUMMER AND LATE POTATOES

An average cut of 8 per cent in total acreage of summer and late potatoes in 1956 was recommended by the U.S. Department of Agriculture in its annual acreage-marketing guides.

A more detailed report, "1956 Acreage-Marketing Guides, Summer and Late Potatoes" will be available for distribution through the State Extension Services within a short time.

Specific acreage guide recommendations for summer and late potatoes by States, are shown in the accompanying table.

1956 ACREAGE GUIDES

Summer and Late Potatoes with Summary for Full Year

Group and State	1956 Acreage Guide	Percentage Guide Is of 1955 Planted Acreage
	1,000 Acres	*Per cent*
Late States:		
Maine	129.2	83
New Hampshire	3.6	100
Vermont	3.4	100
Massachusetts	8.6	99
Rhode Island	4.2	95
Connecticut	8.9	97
New York (L.I.)	51.3	95
New York, Upstate	42.0	100
Pennsylvania	60.0	100
West Virginia	13.0	100
9 Eastern States	324.2	92
9 Central States	328.2	98
11 Western States	352.8	87
29 Late States	1,005.2	92
Summer Commercial		
Virginia	22.9	92
Maryland	3.4	100
Delaware	6.2	75
Kentucky	.7	100
Missouri	.6	100
Kansas	.4	80
Nebraska	1.5	100
Texas	6.2	75
Georgia	.7	100
New Jersey	22.4	99
10 Summer	65.0	91
Winter[1]	10.1	76*
Early Spring[2]	19.4	77*
Late Spring[2]	111.6	89*
Other[3]	105.0	96*
U.S. Total All Seasons	1,316.3	91

[1] Announced August 1955
[2] Announced November 1955
[3] Non-Commercial acreage in early and intermediate States
*Per cent of 1955 harvested acreage

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Well-shaped, mealy potatoes with high specific gravity are wanted by potato processors, potato chip manufacturers and the housewife.

Soluble magnesium is one of the key factors in the growth of high yields of top-grading potatoes. Tests have shown that 40 pounds of soluble magnesium per ton of mixed fertilizer produced yield increases ranging from 13 to 120 bushels of high quality potatoes per acre. *Sul-Po-Mag* in a quality mixed fertilizer gives the crop the magnesium it needs. And it also supplies potassium sulfate, a premium form of potash that is low in chloride and which boosts both production and quality.

The balanced combination of water-soluble magnesium sulfate and potassium sulfate in *Sul-Po-Mag* has increased potato profits for thousands of growers. *Sul-Po-Mag* is available in many of the quality potato fertilizers. It will pay the farmer to always insist on a quality mixed fertilizer containing *Sul-Po-Mag*.

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